[0045] Completely conventional types of ball bearings can be used. These ball bearings **50**, together with the inner and outer ball bearings **48** and **49**, determine the position of the inner half-cylinder **17**. The combination of ball bearings limits the movement of the inner half cylinder **17** to a rotation about the center of the half-cylinder **17**. During this rotation, there is no sliding friction, but only a rolling friction in the ball bearings **48**, **49** and **50**. The ball bearings **48** are each mounted on a steel pin, which is fixed on the outer wall **41**, **43**. The ball bearings **49** are mounted such that they can be easily displaced relative to the inner ball bearing **48**. Both ball bearings **48** and **49** are mounted inside the side slit **52** of the half-cylinder **17**, which can be clearly seen in FIG. **6**. The inner ball bearings **48** are in contact with that edge of the slit **52** nearer the center, and the outer ball bearings **49** are in contact with that edge of the slit **52** further away from the center.

[0046] It will be clear from the description that the rotation module with the inner half-cylinder **17** and outer half-cylinder **18** is statically overdetermined. For this reason, the individual components have to be produced with a high degree of precision. In other embodiments of the invention, it is also possible to have fewer ball bearings, such that the system is not overdetermined, or the ball bearings can be mounted resiliently if the spring forces are greater than the externally applied bearing loads.

[0047] The term half-cylinder in this context does not mean a half cylinder that covers a spatial angle of 180 degrees. The term half-cylinder here means a hollow rotation body which has a substantially cylindrical jacket and which covers an angle of between 130 and 210 degrees. The securing of the cable arrangement permits at most one rotation about this angle minus the angle range necessary for the mounting of the cables. Since this differs depending on the module (upper arm/elbow/wrist), a movement angle for a rotation in the range of approximately 110 to 190 degrees can be covered. The unit can also be designated as a hollow-cylinder part element.

[0048] Although the principle of the components described here is to some extent known from the sensors and robots used in industrial robot technology, the features presented here are of a different scope, particularly since they have to comply with medical regulations when used on patients.

[0049] The most important elements of the solution of the system are that the distal part of the system is constructed as an exoskeleton. The patient's arm is connected to the system at exactly three places with biocompatible cuffs **8**, **9** and **10**. The version described in the illustrative embodiment presented here comprises five actuated degrees of freedom (four without actuated forearm cuff) and permits flexion and extension of the elbow joint and spatial shoulder movements about three degrees of freedom. It also permits pronation/supination of the wrist **7**.

[0050] The advantage of the ball bearings **48**, **49** and **50** is not only the smooth and clearance-free rotation of the inner half-cylinder **17** in the outer half-cylinder **18**, but also the fact that they take up the tilting movements caused by the orthosis by its free movement in space with correspondingly long lever arms from the center of the forearm (eyelets **39**) to the attachment in the area of the wrist **7**, such that basically only rolling friction occurs.

[0051] There are basically two technical possibilities for producing the inner cylinder and outer cylinder **16**/**17**; **20**/**21**; **22**/**23**, that is to say the fundamental hollow rotation body. One possibility is the turning of a full cylinder, which is then cut open. In the illustrative embodiment presented here, the rotation body has by contrast been milled from a block, since the rotation body, in the case of cutting open a full cylinder after it has been turned to its dimensions, can change in shape because of possible stresses in the original aluminum block. A suitable milling machine has a precision of one micron. The optimal width of the groove **52** for the ball bearings was then approximated in small milling steps.

[0052] The advantage of the system according to the invention is that it can move the shoulder, approximated through three rotatory degrees of freedom, and the elbow, approximated through one rotatory degree of freedom, directly and without restriction. A further degree of freedom is afforded by the pronation/supination of the forearm. The illustrative embodiment according to the invention has a low inertia, little friction and minimal play. The actuators are advantageously able to reach the hand of the patient **4** with a tangential speed of up to 1 meter per second, thus applying an acceleration of approximately gravitational acceleration both in acceleration and also in braking.

[0053] The linear drive **11** with the first axis and with the first drive **25** permits the abduction and adduction of the shoulder. The rotation of the shoulder in the horizontal plane is realized with a second rotation drive **26**. This drive **26** is connected directly to the ship of the linear drive **11**. The rotation module has a third drive **29** and permits the internal and external shoulder rotation, since it is connected by a cuff **10** to the upper arm of the patient **4**. The elbow flexion and elbow extension are ensured by means of a fourth rotation drive **32**, with a cuff **9** being connected to the elbow area of the patient **4**. Finally, the pronation/supination is permitted by means of a fifth rotation drive **35**, with a cuff **8** being connected to the wrist area **7** of the patient **4**.

[0054] By virtue of the two non-actuated degrees of freedom, the system is statically determined only in combination with the patient's arm when the orthosis is connected to the linear module **11**. Thus, pretensioning between the robot and the patient's arm can be effectively ruled out.

[0055] Two control types can be provided in particular. For example, any desired free movement of the patient's arm can be permitted, recorded and stored, in which case the respective encoders of the different drives record the axis position and store it in a memory unit. It is thus possible, by direct control of the relevant drives according to the stored encoder positions, to repeat a previously executed movement completely and identically. It is also possible, by moving a patient's arm, to record its existing mobility and store this as a limit value for a movement program.

[0056] It is possible to provide for each user a so-called patient-cooperative control. In such a setup, impedance and admittance control principles are used as a basis for detecting the existing voluntomotoricity of the patient and taking this into consideration in the movement calculation. This means that the effort by the patient to follow a movement predefined by the control is taken into account by the fact that the corresponding actuators help the user less to complete the movement.

[0057] For this patient-cooperative control, the sensor signals of the position sensors and of the force sensors are evaluated. By means of the data signals of the sensors, it is possible for the control electronics to provide a feed-back controlled movement. It is advantageous in particular to provide a screen with a display for presenting an image of the arm of the patient **4**, such that start points and target points can be